Attachment S
Sample Calculations

The MWRA's outfall dilution can be expressed using the following mathematical equation:

$C_l = C_a + [(C_c - C_a)/(1/S_n + 1/S_b - 1/(S_n)(S_b))]$

Given:

C_L = water quality limitation
= the level of a pollutant that is acceptable to meet water quality standards.

C_a = maximum ambient data sample
= level of a pollutant that is sampled from the water column, within fairly close distance to the outfall discharge area.

C_c = water quality criterion
= level set as the standard to meet without dilution.

S_n = nearfield initial dilution
= 70:1

S_b = background farfield dilution
= 150:1 (occurs at a 990 MGD flow rate);
= 256:1 (occurs at a 690 MGD flow rate); and
= 364:1 (occurs at the long-term average flow rate).

Assumptions Used to Determine the Mixing Zone - Dilution:

The most restrictive assumptions were used to determine the MWRA's initial dilution. The list of assumptions are as follows:

a. Flux-Average Nearfield Initial Dilution -

A stratified counterflow will occur whenever wastewater is discharged into an otherwise stagnant environment. To address this phenomenon, two sets of experiments were run: (1) long-duration experiments - to measure stability and temporal variability of the flow field, and (2) dye streaks within a tank - to measure induced-velocity and flux-average dilution. Both sets of experiments were performed under the most critical conditions: late summer stratification and zero current speed. EPA usually defines initial dilution as flux-average dilution. Flux-average dilution was measured directly by discharging a clear effluent and dropping dye crystals into an experimental tank, which formed vertical dye streaks. The deformation of the dye streaks was photographed and video-taped. Although the tests provide only a relatively crude estimate of the volume fluxes, the results imply that the flux-average dilution may only be 10-20% higher than the minimum. That is, the ratio of flux-average to minimum dilution is probably in the range of 1.1 - 1.2. Therefore, the estimated measured values for flux-average dilution are assumed as: 1.15 X the minimum initial dilution, for the draft permit. This value represents the average distribution of dilution over the plume's cross-sectional area.[1]

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[1] Roberts, P.J.W. and Snyder, W.H. "Hydraulic Model Study of the Boston Outfall. II: Environmental Performance," *Journal of Hydraulic Engineering*, Volume 119, No. 9 (September 1993), 944-1000.

b. Background Build-up Entrainment Assumptions -

(1) August - lowest flow month; most conservative month.
(2) 90th percentile - consistent with the Technical Support Document for Water Quality-based Toxics Control (TSD).
(3) 50th percentile - human health is a long term median;
(4) 50th percentile is a long term median flow event.
(5) loading of 1000 - this represents the amount of concentration of pollutant that is introduced into the tank study in order to determine the amount of pollutant that remains after diffusion; the amount itself is relative; the amount into the system divided by the amount out of the system is a ratio of the dilution available. The amount of pollutant out is relative to the flow distribution that you choose to use. EPA and the MADEP used the 90th percentile flow distribution for acute and chronic background farfield dilutions, and the 50th percentile for the human health background farfield dilution.

c. Acute = 150:1 background farfield dilution assumptions -

(1) hourly average flow during the month of August 1990
(2) 90th percentile flow distribution
(3) assumed loading = 1000
(4) concentration at 90th percentile = 6.7
(5) background dilution = 1000/6.7 = 150:1

d. Chronic = 256:1 background farfield dilution assumptions -

(1) 4-day running average flow during the month of August 1990
(2) 90th percentile flow distribution
(3) assumed loading = 1000
(4) concentration at 90th percentile = 3.9
(5) background dilution = 1000/3.9 = 256:1

e. Human Health = 364:1 background farfield dilution assumptions -

(1) 4-day running average flow during the month of August 1990
(2) 50th percentile flow distribution
(3) assumed loading = 1000
(4) concentration at 50th percentile = 2.75
(5) background dilution = 1000/2.75 = 364:1 (When determining limits for human health, nearfield dilution was not included.)

f. Ambient Background Assumptions -

Draft permit limits, and monitoring requirements, are based on incorporating the highest reported ambient water column sampling data that is collected within the closest distance to the outfall discharge area.

<u>Sample Calculations</u>:

$C_L = C_a + [(C_c - C_a)/(1/S_n + 1/S_b - 1/(S_n)(S_b))]$

Given:

C_L = water quality limitation
C_a = maximum ambient data sample

C_c = water quality criterion
S_n = nearfield initial dilution
S_b = background farfield dilution

a. Copper - CHRONIC Water Quality Limitation -

Given:

C_L = unknown (water quality limitation)
C_a = 0.4167 ug/l (maximum ambient data sample)
C_c = 2.9 ug/l (chronic water quality criterion)
S_n = 79.5 (flux-average nearfield dilution at 690 MGD flow rate)
S_b = 256 (farfield dilution, chronic)

$C_L = C_a + [(C_c - C_a)/(1/S_n + 1/S_b - 1/(S_n)(S_b))]$

$C_L = 0.4167 + [(2.9 - 0.4167)/(1/79.5 + 1/256 - 1/(79.5)(256)]$
$C_L = 0.4167 + [(2.4833)/(0.01257 + 0.003906 - (0.000049135)]$
$C_L = 0.4167 + [(2.4833)/(0.01642)]$
$C_L = 0.4167 + [151.1]$
C_L = <u>151.5 ug/l</u> = <u>chronic water quality limitation for copper</u>

b. Copper - ACUTE Water Quality Limitation -

Given:

C_L = unknown (acute water quality limitation)
C_a = 0.4167 ug/l (maximum ambient data sample)
C_c = 2.9 ug/l (acute water quality criterion)
S_n = 71.3 (nearfield flux-average dilution at 990 MGD flow rate)
S_b = 150 (farfield dilution, acute)

$C_L = C_a + [(C_c - C_a)/(1/S_n + 1/S_b - 1/(S_n)(S_b))]$

$C_L = 0.4167 + [(2.9 - 0.4167)/(1/71.3 + 1/150 -1/(71.3)(150)]$
$C_L = 0.4167 + [(2.4833)/(0.014025 + 0.006666 - 0.0000935)]$
$C_L = 0.4167 + [(2.4833)/(0.0207854)]$
$C_L = 0.4167 + [119.47]$
C_L = 119.88 = <u>120 ug/l</u> = <u>acute water quality limitation for copper</u>

c. Aldrin - Chronic HUMAN HEALTH Limitation -

Given:

C_L = unknown (chronic human health limitation)
C_a = 0.0000498 ug/l (maximum ambient data sample)
C_c = 0.00014 ug/l (chronic human health criterion)
S_n = not applicable (nearfield flux-average dilution)
S_b = 364 (farfield dilution, chronic human health)

$C_L = C_a + [(C_c - C_a)/(1/S_n + 1/S_b - 1/(S_n)(S_b))]$

$C_L = 0.0000498 + [(0.00014 - 0.0000498/(1/1000000 + 1/364 -1/(1000000)(364))]$

C_L = 0.000498 +[(0.0000902)/((0.000001 + 0.002747 - 0.000000003))]
C_L = 0.000498 + [(0.0000902)/(0.002747)]
C_L = 0.000498 + [0.032823]
C_L = <u>0.0328 ug/l</u> = <u>chronic human health limitation for aldrin</u>